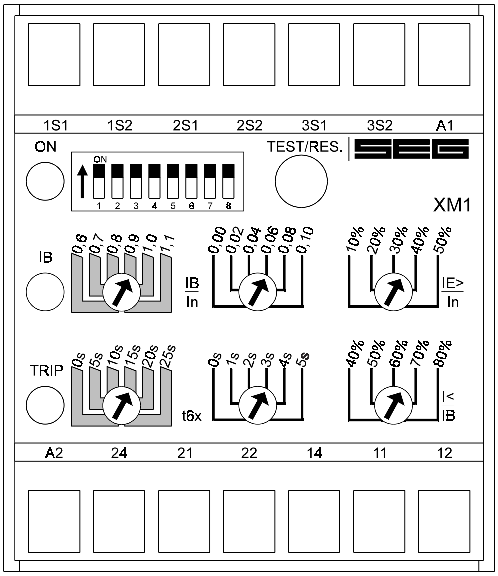
XM1 - Motor protection relay



Contents

1 Applications and features

The *XM1* of the *PROFESSIONAL LINE* is a digital relay for electrical motor protection. Besides its standard applications, the *XM1* is mainly used for motors where normal CBs do not guarantee sufficient protection.

When compared to conventional protection equipment all relays of the *PROFESSIONAL LINE* reflect the superiority of digital protection technique with the following features:

- High measuring accuracy by digital processing
- Fault indication via LEDs
- Extremely wide operating ranges of the supply voltage by universal wide range power supply unit
- Wide setting ranges with very accurately graded
- Data exchange with process management system by serial interface adapter XRS1 which can be retrofitted
- RMS measurement
- Compact design by SMD-technology
- Sealable cover for setting elements

Especially the *XM1* offers the following functions:

- Overload protection with thermal capacity according to I^2t characteristic with adjustable current/time tripping characteristic
- Thermal overcurrent warning via LED with relay output
- Locked rotor (stalling) protection
- Earth fault protection
- Short circuit protection (blocking possible)
- Protection against asymmetric phases (blocking possible)
- Underload protection (blocking possible)
- Automatic/manual reset
- Storage of starting heat load
- Non-volatile memory of heat load
- Restart blocking at insufficient motor heat reserve
- Data exchange with process management system by serial interface adapter *XRS1* which can be retrofitted

2 Design

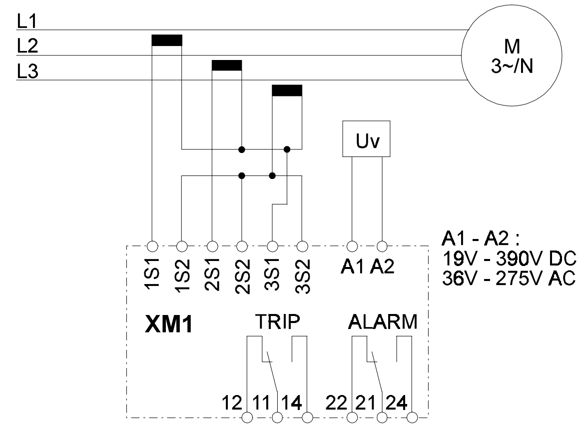


Fig. 2.1: Connection with 3 phase CTs

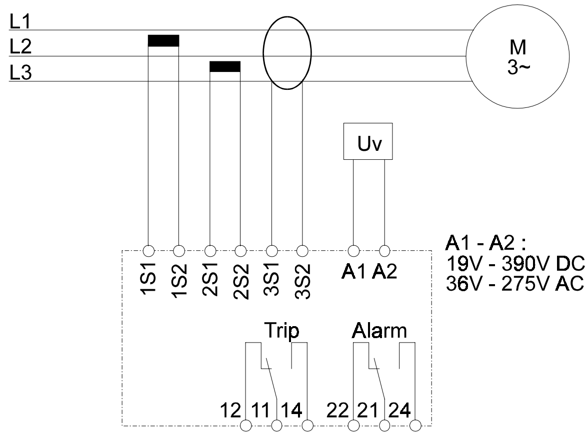


Fig. 2.2: Connectionexample with 2 phase CTs and 1 core balance CT (Type of connection A)

Type of connection	1S	2S
A	L1	L2
B	L2	L3
C	L3	L1

Table 2.1: Further connection possibilities

Output relays

The *XM1* is provided with 2 output relays:

- Trip relay
  The trip relay is a normally-on relay and energizes when the *XM1* has detected a fault.

- Alarm relay
  The alarm relay is a normally-off relay and is energized in faultless condition, when supply voltage is applied to the *XM1*.

Analog inputs

Analog input signals of the motor currents are led to the protection relay via terminals 1S1 - 3S2. The *XM1* can either be connected with three identical CTs in Holmgreen connection (Fig. 2.1) or with two phase CTs and one core balance CT (Fig. 2.2). At inputs 1S1/1S2 and 2S1/2S2, the *XM1* measures conductor currents L1 or L3 and at input 3S1/3S2 the earth current. Dependent on the relay type, CTs with either 1A or 5 A can be used.

Auxiliary voltage supply

Unit *XM1* needs a separate auxiliary voltage supply U_V. Unit *XM1* has an integrated wide range power supply. Voltages in the range form 19-390 V DC or 36-275 V AC can be applied at connection terminals A1 (L-) and A2 (L+). The voltage range does not need specificly to be set.

Contact positions

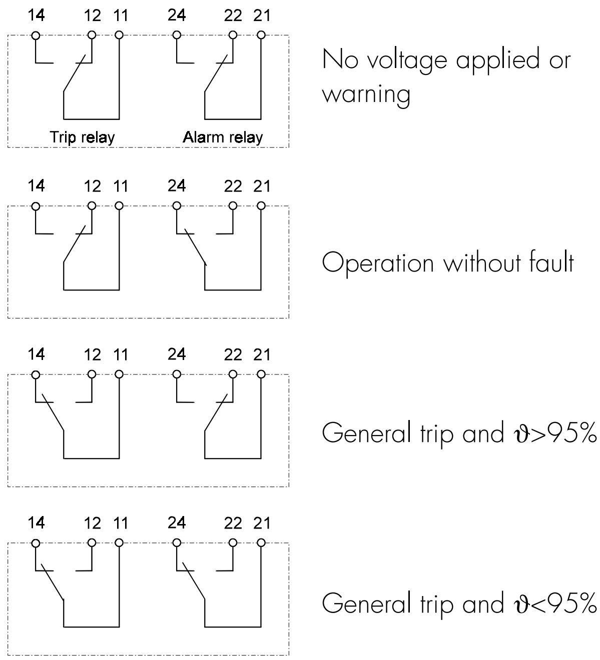


Fig. 2.3: Contact positions

3 Working principle

3.1 Overload protection

When a motor is operated at its rated current I_{Mn}, normally it reaches about half of its max. thermal capacity. Operating conditions above I_{Mn} lead to further temperature rise which is only permissible up to the max. temperature limit. The maximal steady-state temperature is indicated by the insulation class. On the basis of adjustment and current measuring data, the *XM1* simulates an internal model of the motor temperature, based on I^2t motor temperature characteristic. By this the heat capacity of the motor can be fully utilized for short-term overloads, providing 100% protection at the same time. Rated motor current I_{Mn} and time t_{6x} are the adjustable parameters to define the motor model. The rated motor current is stated as percentage of the rated relay current (1A or 5A) and set as basis current IB. Time t_{6x} indicates when the cold motor has reached the max. permissible temperature (stated by the motor manufacturer) at 6 times rated current.
If the calculated motor temperature reaches 95% of its permissible value, the warning element is activated and the output relay releases. Dependent on the application, deduction of the motor load can be initiated by this signal. Otherwise the motor temperature would keep rising and when exceeding the max. temperature, the trip relay would be activated.

After start up, the *XM1* stores the heat load of the motor. After tripping due to overload, the *XM1* can only be reset if the motor has cooled down at least by the amount of heat causing the trip. In this case the cooling constant is twice the heating constant. In normal operation, if there is no overload tripping , the *XM1* computes with equal constants. The termal memory is non-volatile, even when the aux. voltage fails.

3.2 Stalling protection

A stalled rotor after start-up or a torque which is too high is identified by the *XM1* on the motor current criterion, i.e. that it exceeds the value of $3.5 \times I_B$ for longer than 1s. This protective function can be switched off by the DIP switch 2.

3.3 Earth fault protection

The *XM1* provides protection against earth fault. If the earth fault current set at the potentiometer IE>/In is exceeded for more than 1s, the trip relay picks-up. This function can be switched off. If the short circuit protection (see 3.4) is enabled, the earth fault element trips with the relay's time element.

3.4 Short circuit protection

When using a circuit-breaker instead of a contactor, the short circuit element of the *XM1*, in case of a failure, gives the tripping command to the circuit-breaker (DIP-switch 5 ON). If the short circuit current exceeds 10 times IB, the *XM1* trips with its time element.

When using contactors (DIP-switch 5 OFF), this function can be switched off.
If the short circuit function is switched off and a fault current of 7 times In occurs, tripping of the relay is inhibited to prevent welding of the contactor's contacts. In this case the failure must be switched off by other protection devices.

3.5 Undercurrent protection

For some applications an unloaded motor is undesireable (e.g. protection against a pump running dry). In such cases the motor current must be above a minimal value. The percentage of the basic current value can be set at potentiometer I</IB in the range from 40 - 80%. If the motor current stays below this value for longer than 3s, the warning relay releases.

3.6 Current unbalance protection

If the motor current becomes unbalanced due to a conductor break or short circuit in the windings, the *XM1* trips in accordance with a fixed time characteristic, conditional on the proportion of current unbalance. *XM1* calculates the current unbalance„A" from the two measured conductor currents by using the following formula:

$$A = \frac{I_{max} - I_{min}}{I_{max}} \cdot 100\%$$

A = Current unbalance (100% = phase failure)
I_{max} = the higher one of the two conductor currents
I_{min} = the lower one of the two conductor currents

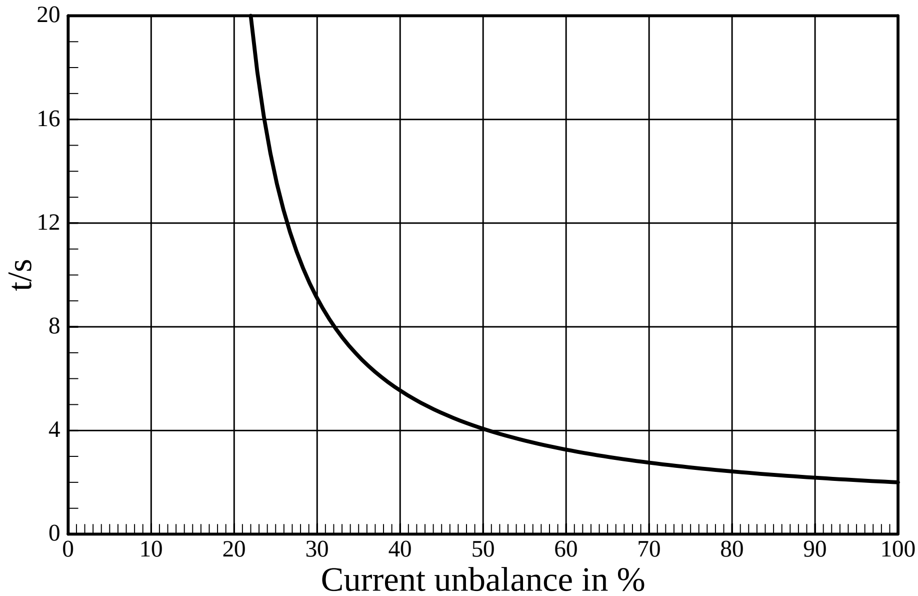


Fig. 3.1: Time characteristic of unbalance current protection

4 Operation and settings

All operating elements needed for setting parameters are located on the front plate as well as all display elements.
Because of this all adjustments of the unit can be made or changed without disconnecting the unit from the DIN-rail.

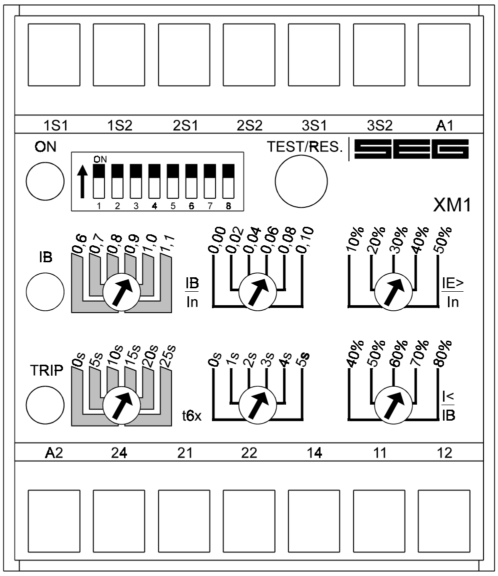


Fig. 4.1: Front plate

For adjustment of the unit the transparent cover has to be opened as illustrated. Do not use force! The transparent cover has two inserts for labels.

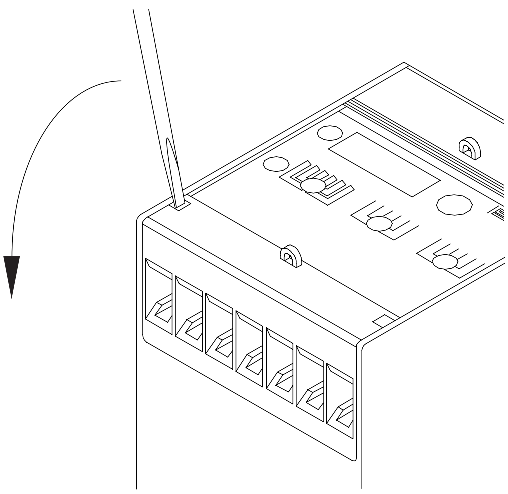


Fig. 4.2: How to open the transparent cover

LEDs

LED "ON" is used for display of the readiness for operation (at applied auxiliary voltage Uv). The LEDs IB and TRIP signalize warning and trip conditions of the relay. Through different blinking sequences the kind of failure can be determined (refer to chapter 4.2.1).

TEST/RESET button
By means of this P.B. the relay is reset and all faults, configurated to be manually reset, are acknowledged. This push button is used for test trip of the relay. A test trip can only be performed, when no current flows into the measuring inputs. After pressing the push button for 1s, the trip relay trips and LED TRIP lights up. Releasing the push button finishes the test procedure.

4.1 Setting of DIP-switches and potentiometers

The DIP-switch block on the front plate of the *XM1* is used for setting of function parameters:

DIP-switches	OFF	ON	Function
1	inactive	active	Overload alarm
2	inactive	active	Protection against earth fault and rotor blockage
3	inactive	active	Undercurrent supervision
4	inactive	active	Protection against current unbalance and phase failure
5	inactive	active	Short circuit protection
6	manual	automatic	Reset after overload
7	manual	automatic	Reset after earth fault, current unbalance and rotor blockage
8			This DIP switch must be in position OFF

Table 4.1: Functions of DIP switches

Overload alarm
If DIP switch 1 is in position OFF, overload alarm is blocked.

Protection against earth fault and rotor blockage
If DIP switch 2 is in position ON, earth fault supervision and rotor blockage protection become active.

Underload supervision
In case the motor current drops below the set value after a start, the *XM1* trips after 3 s if DIP switch 3 is in position ON.

Current unbalance protection
As from a motor current of 20% x IB, current unbalance protection becomes active. A phase failure, too is being detected by the current unbalance protection. If DIP switch 4 is in ON position, the current unbalance protection is activated. Below 0.1 x In and above 2 x In the current unbalance protection is deactivated.

Short circuit protection
The short circuit element is blocked, if the DIP-switch 5 is in position OFF.

Auto reset
By DIP switches 6 and 7 can be determined whether the trip relay shall be reset automatically or manually by pressing the RESET push button.

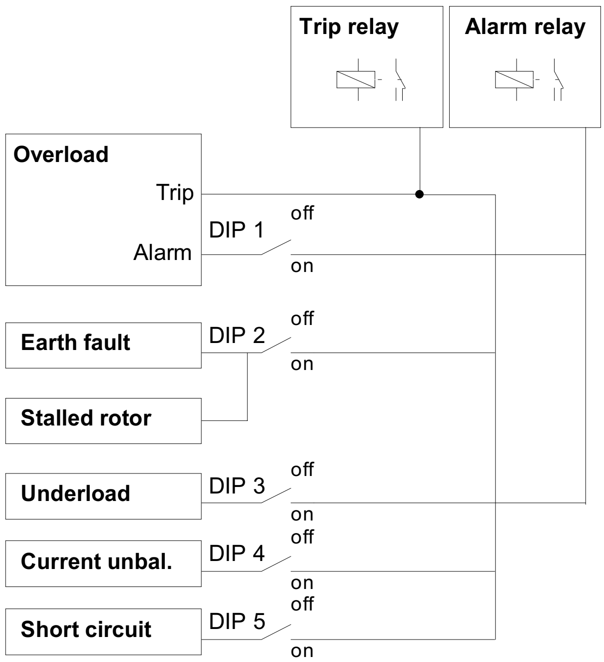


Fig.: 4.2: Allocation of output relays

4.2 Setting of the tripping values

The *Professional Line* units have the unique possibility of high accuracy fine adjustments. For this, two potentiometers are used. The coarse setting potentiometer can be set in discrete steps. A second fine adjustment potentiometer is then used for continuously variable setting. Adding of the two values results in the precise tripping value for basic current I_B and motor time constant quantity t_{6x}. All other parameters are set by individual potentiometers.

Basic current IB/In

The basic current is adjustable from 0.6 - 1.2 x In. If the basic current is exceeded by 5%, trip calculation starts and LED IB lights up. (The arrow of the coarse potentiometer should always be in the middle of the marked bars otherwise a definite setting value cannot be obtained.)

Example: IB/In=0.96xIn

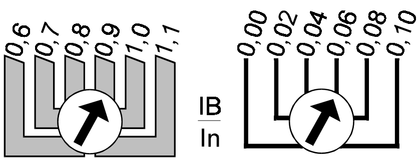


Fig. 4.3: Setting of the basic current

Use of current transformers

When using current transformers, the transformer ratio muß be taken into account at setting of the basic current.

Example:

Motor:	75 kW
Motor rated current I_{Mn}:	160 A
Rated current of *XM1*:	5 A
CT ratio:	200/5
Motor rated current related to the secondary side of the CT I_{Msec}:	4 A

That results in a setting of:

$$\frac{IB}{In} = \frac{I_{Mnsec}}{In} = \frac{4A}{5A} = \underline{\underline{0{,}8}}$$

Motor time constant t_{6x}

The motor time constant t_{6x} can be set on the two potentiometers. Here, too values of coarse and fine setting potentiometer are added. If the motor characteristics are not available, a value of 1.1 x start-up time can be assumed for the time constant quantity.

Example: t_{6x}=18 s

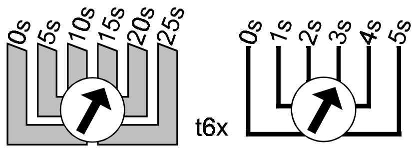


Fig. 4.4: Setting of the motor time constant quantity

Earth fault tripping value

The earth fault tripping value is adjustable in the range of 10% to 50% In.
Setting recommendation: 10% for resonant earthed systems and 50% for solidly earthed systems.

Underload tripping value

The underload tripping value is adjustable in the range of 40% to 80% IB. This setting value refers to basic current IB.

4.2.1 Fault indication

When the relay alarms or trips the LEDs on the front panel will flash indicating the type of fault the relay is seeing.The LED flashes a certain number of times very quickly, pauses then repeates the process. The LED will carry on indicating the fault until it has been cleared: For example the Trip LED flashing four times indicates that there is an unbalance fault on the relay.
This then enables the user to clear the fault that is causing the trip.

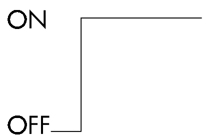
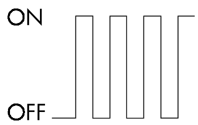
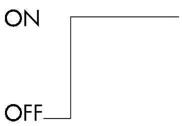
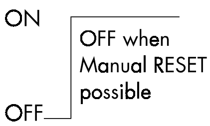
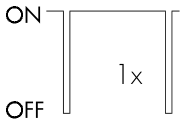
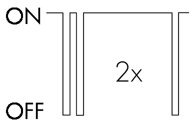
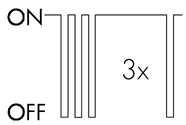
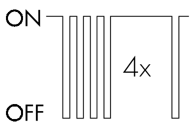
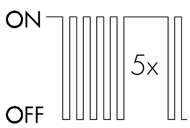
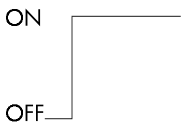
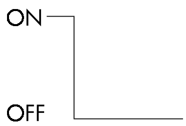
Function	LED TRIP	LED IB	ON LED
Thermal pickup			
Overload Pre-alarm			
Overload trip			
Stall protection			
Earth fault			
Underload			
Unbalance			
Short circuit			
Internal fault			

Fig. 4.5: Fault indication

4.3 Thermal overload tripping characteristics

The *XM1* simulates the thermal condition of the motor by means of a thermal register. The heating of the register is related to the square of the largest of the three line currents. The rate of cooling of the thermal register is directly related to the rate of heating. The value of the thermal register is called thermal capacity and it is used to simulate motor temperature.

100 percent thermal capacity means the motor temperature has reached the maximum allowed and is the level at which an overload trip will occur.

When the motor is stopped for a long period of time the thermal capacity used is zero, this is known as the 'cold condition', and the motor has 100 percent of it's thermal capacity available for heating before a trip will occur.

When a motor starts and is running, its temperature increases. After running at normal FLC for a period of time, the motor will have reached a hot condition and a lower value of thermal capacity will be available. The remaining thermal capacity at previous operation at FLC is a specific value of the motor and is called K_{HC}. The tripping delay at overload is calculated by the following equation:

$$\frac{t}{t_{6x}} = 32 \cdot ln \left[\frac{I^2 - (1 - K_{HC}) \cdot I^2_{pre\text{-}load}}{(I^2 - IB^2)} \right]$$

Where:
- *ln[ ]* = logarithm to base e
- t = Trip delay
- I_{Mn} = Motor FLC
- t_{6X} = Tripping time at 6 x FLC
- I = Overload current
- $I_{pre\text{-}load}$ = Motor current before overload
- K_{HC} = Hot/cold ratio
- IB = Basic current

The *XM1* has a fixed hot/cold ratio of 50%. So the equation is reduced to:

$$\frac{t}{t_{6x}} = 32 \cdot ln \left[\frac{I^2 - 0{,}5 \cdot I^2_{pre\text{-}load}}{(I^2 - IB^2)} \right]$$

The following diagram shows tripping curves at different preloads calculated by the above equation.

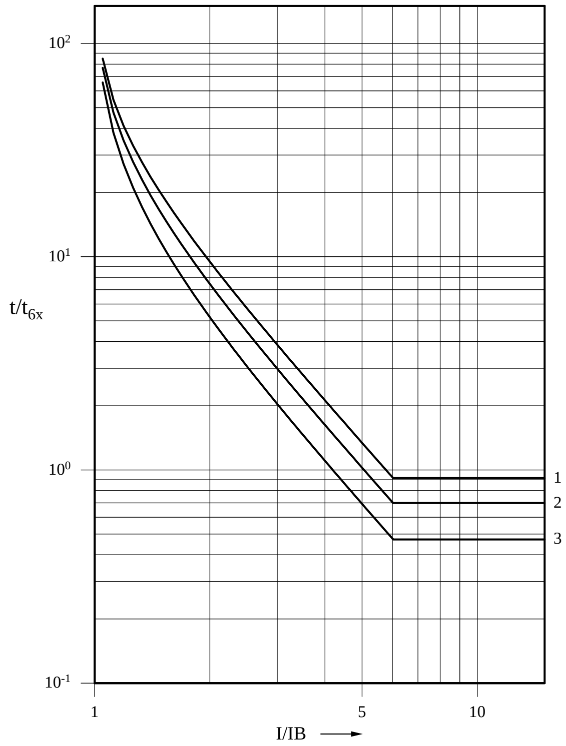


Fig. 4.7: Tripping curves

Curve 1: Cold condition of the motor, pre-load = 0%
Curve 2: Pre-load = 70%
Curve 3: Hot condition of the motor, pre-load = 100%
Overload pickup current: 1.05 x IB

If the motor current exceeds the preset overload pickup current, the value of the thermal register increases. When 100% percent of the thermal equivalent is reached, the relay trips and the motor is switched off. The time to trip depends on the remaining thermal capacity and the preset t_{6X} time.
The t_{6X} time specifies the time, a cold motor takes to reach its maximum admissible operating temperature, when running at 6 times FLC. The heating constant of the motor is equal to the t_{6X} time x 32 seconds. This value is usually shown in the data sheets of the motor manufacturer. If no data are available on t_{6X}, the following settings can be assumed:

- For D.O.L. starters:
  $t_{6X} \cong 1.1$ x starting time of the motor

- For star/delta starters:
  $t_{6X} \cong 0.35$ x starting time of the motor

4.4 Communication via serial interface adapter XRS1

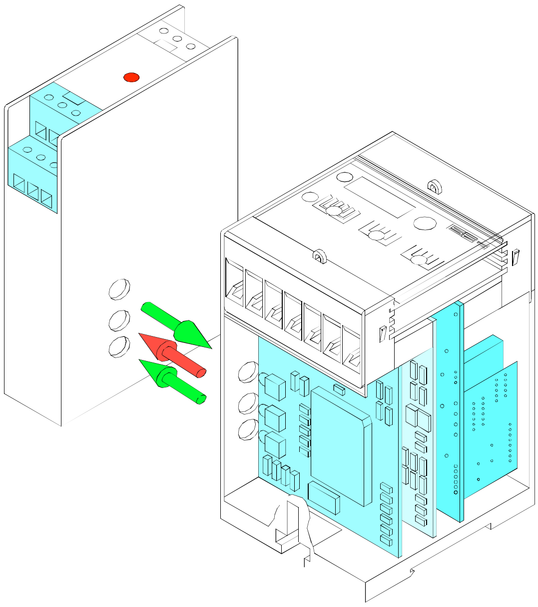


Fig. 4.8: Communication principle

For communication of the units with a superior management system, the interface adapter XRS1 is available for data transmission, including the diagnosis and setting software HTL/PL-Soft3 for our relays. This adapter can easily be retrofitted at the side of the relay. Screw terminals simplify its installation. Optical transmission of this adapter makes galvanic isolation of the relay possible. Aided by the software, actual measured values can be processed, relay parameters set and protection functions programmed at the output relays. Information about unit XRS1 in detail can be taken from the description of this unit.

4.4.1 Serial Number

To set the serial number follow the procedure below.

1. Power off the unit.
2. Set DIP switch 7 to OFF and DIP switch 8 to ON.
3. Set DIPs 1 through 5 to the required communication ID (0 = OFF, 1 - 31 = com. ID).
4. Power up the unit.
5. Press the TEST/RESET button. The LEDs TRIP and IB will flash momentarily.
6. Power off the unit and reset the DIP switches to their previous settings.

DIP- switch	Value
1	1
2	2
3	4
4	8
5	16

Table 4.1: Value of the DIP-switches 1 - 5:

Example:
If a communication ID of 21 is required, the DIPs 1, 3 and 5 have to be set to ON.

5 Relay case and technical data

5.1 Relay case

Relay *XM1* is designed to be fastened onto DIN-rail acc. to DIN EN 50022, the same as all units of the PROFESSIONAL LINE.

The front plate of the relay is protected with a sealable transparent cover (IP40).

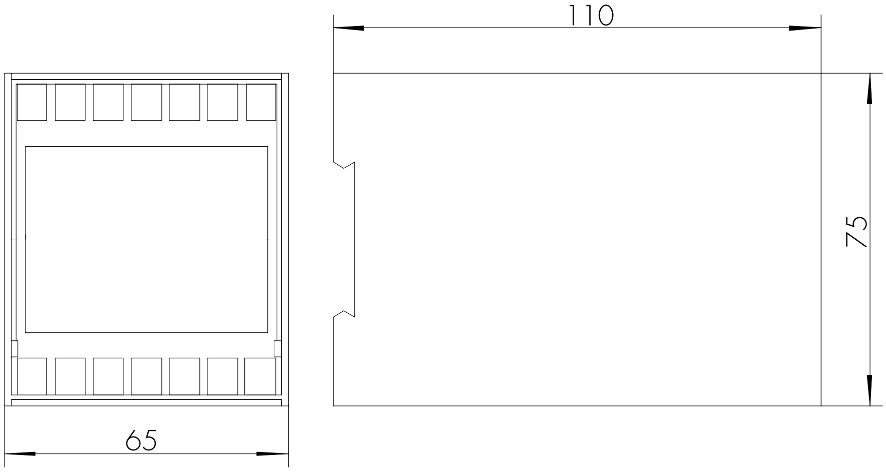


Fig. 5.1: Dimensional drawing

Connection terminals

The connection of up to a maximum 2 x 2.5 mm^2 cross-section conductors is possible. For this the transparent cover of the unit has to be removed.

5.2 Technical data

Measuring input circuits

Rated current I_N:	1 A or 5 A	
Rated frequency range:	40 Hz - 70 Hz	
Thermal withstand capability		
in current circuits:	dynamic current withstand (half wave)	$250 \times I_N$
	for 1 s	$100 \times I_N$
	for 10 s	$30 \times I_N$
	continuously	$4 \times I_N$
Power consumption	at In = 1 A 0.1 VA	
in current circuit	at In = 5 A 0.1 VA	
Basic accuracy of current:	±3 % of the setting value	

Auxiliary voltage

Rated auxiliary voltage U_V:	36 - 275 V AC or 19 - 390 V DC
Power consumption:	4 W
Maximal permissible interruption	$U_V = 24\ V_{DC}$: $t_u = 8$ ms, $U_V = 48\ V_{DC}$: $t_u = 35$ ms
duration of aux. voltage t_u:	$U_V > 60\ V_{DC}$: $t_u = 50$ ms

Common data

Dropout to pickup ratio:	97%
Resetting time from pickup:	<50 ms
Returning time from trip:	200 ms

Output relay

Number of relays:	2	
Contacts:	1 changeover contact	
Maximum breaking capacity:	ohmic 1250 VA/AC resp. 120 W/DC	
	inductive 500 VA/AC resp. 75 W/DC	
Max. rated voltage:	250 V AC	
	220 V DC	ohmic load Imax. = 0,2 A
		inductive load Imax. = 0,1 A at L/R ≤ 50 ms
	24 V DC	inductive load Imax. = 5 A
Minimum load:	1 W / 1 VA at Umin ≥ 10 V	
Maximum rated current:	5 A	
Making current (16ms):	20 A	
Contact life span:	10^5 operations at max. breaking capacity	

System data

Overload function	
Setting range IB/In:	0.6 - 1.2 × In
Setting resolution:	1%
Setting range t_{6x}:	0.5 - 30 s
Setting resolution:	0.5 s
Prealarm:	>95% of the permissible thermal load
Cooling down time constant quantity:	1 × warming-up time constant quantity after overload alarm 0.5 × warming-up time constant quantity without alarm
Asymmetric protection:	
Working range:	I_{Motor} >20% × IB
Tripping delay:	see characteristic fig. 3.1
Rotor blockage:	
Working range:	I >350% × IB
Tripping delay:	1 s
Undercurrent	
Setting range:	40% - 80% of IB, adjustable to 5%
Tripping delay:	3 s
Short circuit:	10 x IB (tripping with relay time element)
Earth fault	
Setting range:	10% - 50% of In, adjustable to 5%
Tripping delay:	1 s (tripping with relay time element, if short circuit function is enabled)
Ambient conditions	
Storage and transport:	-25°C to 70°C
Operation:	-25°C to 70°C
Design standard	
Constant climate class F acc.to DIN 40040 and DIN IEC 68, T.2-3:	more than 56 days at 40° C and 95% relative humidity
High voltage test acc. to VDE 0435, part 303	
Voltage test:	2.5 kV (eff.) /50 Hz; 1 min
Surge voltage test:	5 kV; 1.2/50 µs, 0.5 J
High frequency test:	2.5 kV/1 MHz
Electrostatic discharge (ESD) acc. to VDE 0843, part 2:	8 kV
Radiated electromagnetic field acc. to VDE 0843, part 3:	10 V/m
Electrical fast transient (Burst) acc. to VDE 0843, part 4:	4 kV/2.5kHz, 15 ms
Radio interference suppression test acc. to DIN57871 and VDE0871:	limit value class A

Mechanical test:	
Shock:	class 1 acc. to DIN IEC 255-21-2
Vibration:	class 1 acc. to DIN IEC 255-21-1
Degree of protection:	IP40 (case and terminals)
Weight:	250 g
Relay case material:	self-extinguishing

6 Order form

Motor protection relay	***XM1-***	
Rated currrent:	1 A	**1**
	5 A	**5**

Technical data subject to change without notice!

Setting-list *XM1*

Project: ____________________ SEG job.-no.: ____________________

Function group: = ____________ Location: + ________ Relay code: - ____________________

Relay functions: ____________________ Date: ____________________

Setting of parameters

Function		Unit	Default settings	Actual settings
t6x	Motor time constant	s	0	
IB	Basic current	x In	0.6	
IE>	Earth fault current	% In	10	
I<	Underload	% IB	40	

DIP-switch	Function	Default settings	Actual settings
1	Overload alarm	disabled	
2	Earth fault and stalling protection	disabled	
3	Underload protection	disabled	
4	Current unbalance and phase failure	disabled	
5	Short circuit protection	disabled	
6	Reset after overload	manual	
7	Reset after earth fault, current unbalance and stalled rotor	manual	
8	This DIP- switch must be in position OFF		

Schaltanlagen-Elektronik-Geräte GmbH & Co. KG
Abteilung Gerätevertrieb / Electronic Devices Sales Department
Krefelder Weg 47 · D - 47906 Kempen (Germany)
Postfach 10 07 67 (P.O.B.) · D - 47884 Kempen (Germany)
Tel.: +49 (0)21 52 1 45-1 · Fax.: +49 (0)21 52 1 45-3 54
e-mail: electronics@avkseg.com